Hist Ophthal Intern 2016, Vol.2: 103-108



# Seen through a Pinhole*

by

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**Abstract**
Purpose: To review some phenomena associated with light passing through a pinhole on the way to understanding the optical and visual mechanisms involved.
Methods: Data from self and normal cohorts in private practice setting with review of literature.
Results: The effect of light passing through a small aperture was recorded in China as early as the 5th cent. BC.. Christopher Scheiner was first to compare the optics of the eye to a camera obscura. The image projected on the back wall through the camera's pinhole aperture (as in the eye) was inverted, but looked at directly through the hole it is erect. Perhaps due to the Stiles-Crawford effect and Lateral Inhibition Effect that obscure the more inclined rays of the inverted image. "Entoptoscopes" were invented to view entoptic phenomena in the eye. Seen are also images of the surface of the cornea which move with blinking, in addition to optical changes in one's lens and vitreous. Scheiner used double pinholes to demonstrate for the first time the refractive state of the eye. Modern keratometers and autorefractor are built on this principle. Cogan invented a double pinhole card to measure the size of the pupil. Double pinholes were also used to explore the accuracy of accommodation.
**Conclusion**: The phenomenon where an image is projected inverted through a pinhole yet is seen erect when viewed directly may be explained by the Stiles-Crawford Effect and Lateral Inhibition.
**Keywords**: Pinhole; double pinhole; Lateral Inhibition; Stiles-Crawford Effect; Scheiner; entoptic image.

## Background

In daily practice the pinhole is used to test the potential visual acuity, particularly in cases of refractive errors and media opacities. The effect produced by light's passage through a small aperture – a pinhole – is said to have been recorded in China by the Mohist philosopher Mozi as early as the 5th century BC. The inverted image projected on a surface was mentioned by Duan Chengshi during the Tang Dynasty (618-907), and the camera obscura was explored there soon thereafter[1] (Fig.1a & 1b).

Aristotle in the 4th Century BC noted in addition that light passing through a rectangular peep-hole appeared circular. A pinhole is understood to be an opening of 0.5 to 5 mm in an opaque board. Generally the smaller the hole the sharper the directly seen image, but the dimmer the projected inverted image.

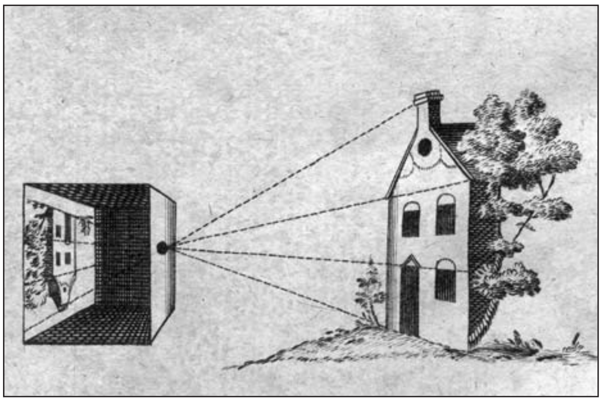

Fig.1a *The camera obscura explained in Priestley´s History of Optics (German edition of 1775)*

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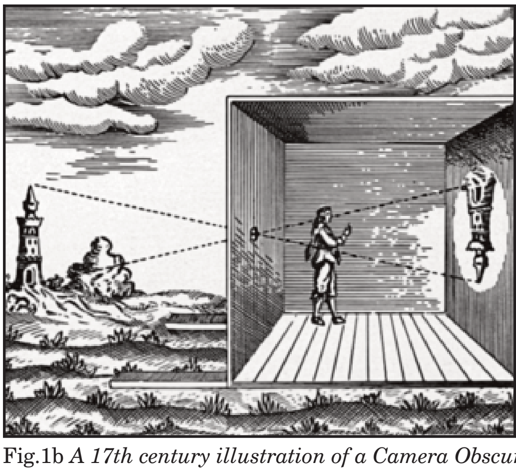

Fig.1b *A 17th century illustration of a Camera Obscura*

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*Presented in part at the Cogan Society meeting 2015 and in a poster American Academy Ophthalmology meeting, Chicago, 2016.

Aristotle's descriptions were included in Alhazen's (965-1038) classical book on optics, which then in the Renaissance gave rise to a voluminous literature speculating why an aperture of any shape always gave rise to a circular image.[2,3,4]

The term 'pin-hole' was first used by James Ferguson in 1764.[5]

The first photo (fig.1c & d) with a camera was taken in Paris by Joseph Nièpce (in 1826 or 1827) after the invention of photographic plates. He and followers needed several hours of exposure for good pictures. The diminished intensity of the pinhole image makes it somewhat harmless to the eye when viewing solar eclipses.

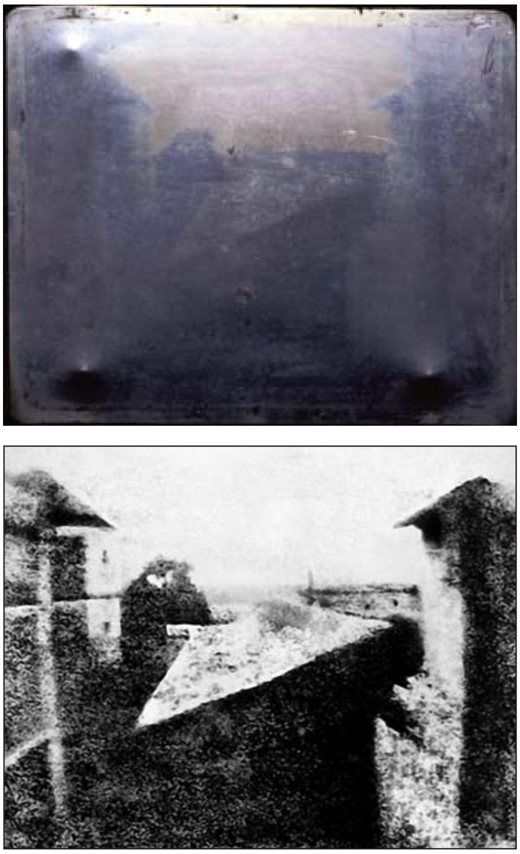

Fig.1c & 1d *Above the original first known and preserved photographic plate made by Nièpce with a camera. Beneath the same photograph enhanced by means of modern scanning methods. The original is kept at the Harry Ranson Center at the University of Texas at Austin.*
www.hrc.utexas.edu/exhibitions/permanent/firstphotograph/

Photographers celebrate a World Pinhole Day, held on the last Sunday of April.

Clinically, Ambroise Paré (1510–1590) constructed pinhole spectacles for the correction of strabismus, with the hope that looking through a small window fixed in front of the eye would force the eyes to straighten.

In 1857 Serre d'Uzes (1802–1870) invented spectacles with a movable pinhole in front of each eye (Fig 3, p.105), called '*Lunette panoptique*', for the purpose of always seeing clearly whatever the refractive error.[6]

Thereafter the pinhole gradually entered the routine diagnostic armamentarium.

**Observations**

Illustrating the rectilinear propagation of light, Christoph Scheiner (1575-1650) explained theoretically how one side of an object seen through a pinhole would be obscured by a screen introduced near the eye from the opposite side. (Fig.2, p.105),[7,8]

On looking through a pinhole it was often said: "The human eye and the photographic camera are modifications of the camera obscura."[1] "If the hole is small enough, all influence of refraction will be eliminated, and a clear image will thus be formed in the same manner as is seen in the pinhole camera"[9] [emphasis added].

Indeed, the pinhole test routinely used in daily practice is a quick method of distinguishing poor vision due to refractive errors from that due to organic pathology.

When standing in a dark chamber (camera obscura) looking at its back wall the picture projected through a small hole in the front wall is seen inverted, but, alas, looking out directly through this hole it is erect (Fig. 1b, p.103). If the picture is inverted by the pinhole, as cast on the back wall of the camera, and then again by the ocular refractive media, it ends on the retina erect, and therefore should be perceived as inverted, which is not the case.

A camera obscura was constructed from a cardboard box with a front of 8 x 10 cm and about 20 cm long. A hole about 3 mm wide was made in the front wall and a transparent paper replaced the opposite one. The image of an arrow, painted on a light bulb

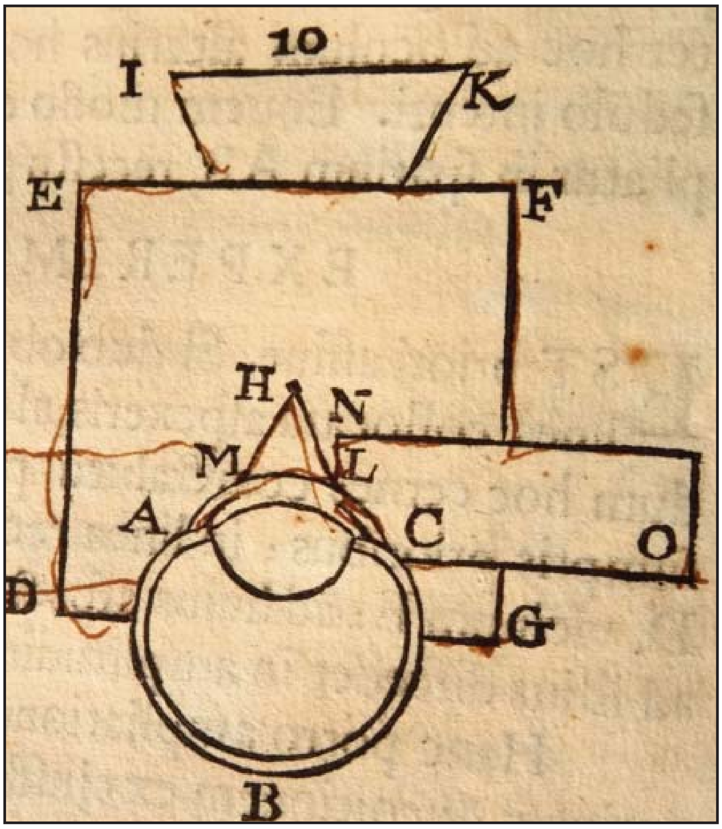


Fig 2. *Screen CO in front of the eye obscures opposite side I of object seen through a pinhole (Scheiner 1619).*

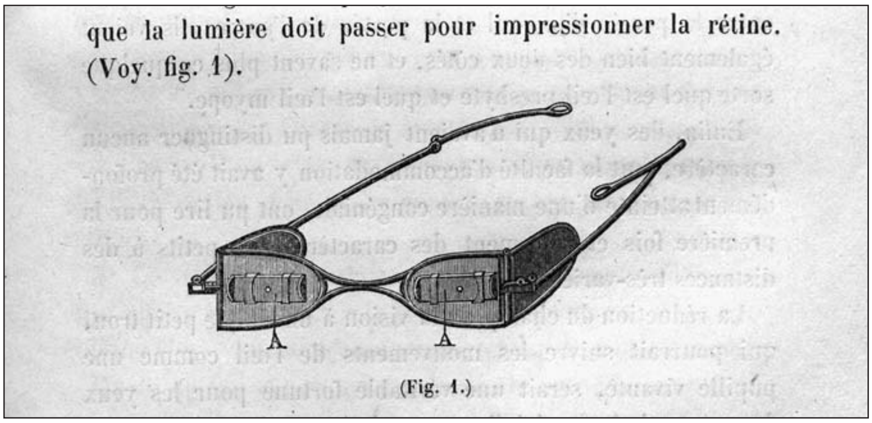


Fig.3: *Auguste Serre (d'Uzes) (1802–1870)*
Serre´s invention as published 1857 in volume 38 of the *Annales d´Oculistique*.

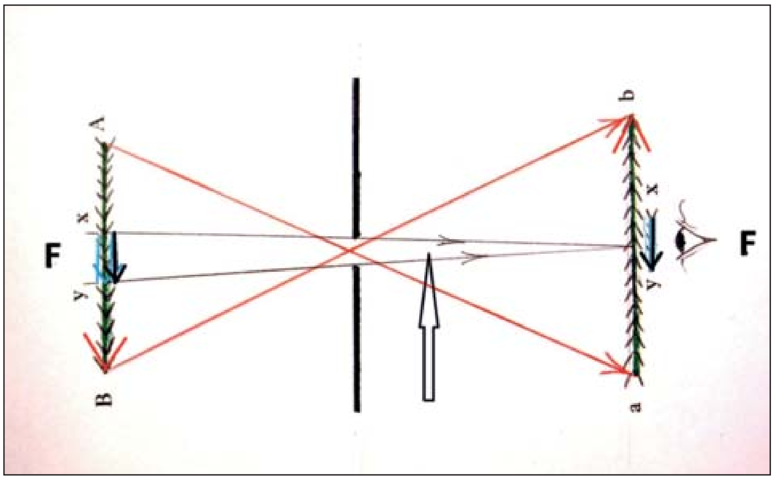


Fig 4. *Object AB projects inverted (ab) by the pinhole, but seen erect (xy).*

**§ 15. Die entoptischen Erscheinungen.**

Das in das Auge einfallende Licht macht unter gewissen Bedingungen eine Reihe von Gegenständen sichtbar, welche sich im Auge selbst befinden. Solche Wahrnehmungen nennt man entoptische. Unter gewöhnlichen Umständen werfen kleine dunkle Körper, die im Glaskörper oder der Linse und wässerigen Feuchtigkeit schweben, keinen sichtbaren Schatten, und werden deshalb nicht bemerkt. Der Grund davon ist, daſs durch jeden Theil der Pupille meist gleichmäſsig Licht eindringt, und somit für die Beleuchtung der hinteren Augenkammer die ganze Pupille gleichsam die leuchtende Fläche bildet. Es ist aber bekannt, daſs, wenn Licht von einer sehr breiten Fläche ausgeht, nur breite Gegenstände, oder solche Gegenstände, welche der den Schatten auffangenden Fläche sehr nahe sind, einen sichtbaren Schatten werfen.

Nun giebt es im Auge allerdings Gegenstände, nämlich die Gefäſse der Netzhaut, welche sehr nahe vor der lichtempfindenden Fläche des Auges sich befinden, und daher immer einen Schatten auf die dahinter liegenden Theile der Netzhaut werfen. Aber eben weil diese Theile der Netzhaut hinter den Gefäſsen immer beschattet sind, und der beschattete Zustand für sie der normale ist, nehmen sie ihn nur unter besonderen Umständen wahr, welche wir weiter unten näher besprechen wollen.

Zunächst wende ich mich zu den in den durchsichtigen Mitteln des Auges enthaltenen kleinen schattengebenden Körpern. Um sie wahrzunehmen, muſs man Licht von einer sehr kleinen leuchtenden Stelle, welche sich sehr nahe vor dem Auge befindet, in das Auge fallen lassen. Zu dem Zwecke kann man entweder das im Focus einer kleinen Sammellinse entworfene Bild einer fernen Lichtflamme nahe vor das Auge bringen, oder ein kleines gut polirtes metallisches Knöpfchen, welches von der Sonne oder einer Lampe beschienen wird, oder einen Schirm von dunklem Papier, welcher Licht durch eine sehr kleine Öffnung fallen läſst. Am zweckmäſsigsten ist es, eine Sammellinse von groſser Apertur und kleiner Brennweite *a Fig. 89* aufzustellen; vor ihr in einiger Entfernung eine Lichtflamme *b*, von der die Linse in ihrem Brennpunkte ein verkleinertes Bild entwirft. Dann stellt man hier einen undurchsichtigen dunklen Schirm *c* mit kleiner Öffnung so auf, daſs das Bild der Flamme auf diese Öffnung fällt. Durch die Öffnung

*Fig. 89.*

Fig.5
*Helmholtz´explaining of Entoptic phenomena in the second German edition of his treatise of physiological optics (1896)*

pointing upwards was projected pointing down on the camera's back wall (It may be made sharper by a + 5 diopter lens placed near the pinhole) (Fig.4, p.106).

A screen introduced in front of the camera's pinhole from above will shade the image on its back wall from below, and vice versa. when the screen is introduced behind the pinhole the shade is formed on the same side whence the screen entered. On the other hand, when looking through a pinhole directly at an object, such as the visual-acuity chart on the wall, it looks erect (and sharp). When a screen is now introduced behind the pinhole, the letters look just as erect as when introduced in front of it (or without a pinhole), but the whole chart is obscured on the opposite side! Looking through a pinhole the scenery is apparently seen both erect (the letters) and inverted (the whole chart)!

Why does an erect object when viewed directly through a pinhole appear erect, yet at the same time its projection is inverted? The phenomenon is probably due to the Stiles - Crawford Effect,[10] and Lateral Inhibition[11] which says that light incident vertically on the receptive retinal elements engenders a stronger response than when incident obliquely. The oblique rays producing the inverted image, as seen in the camera obscura, though too weak to impress the cortical visual centers may yet add to the general view of the direct image. Or else, the strong direct light rays forming the erect image inhibit the perception of the inverted weak ones by Lateral Inhibition[7] between retinal elements.

**Entoptic views**

Helmholtz and others built special instruments to view entoptic phenomena,[12] "entoptoscopes",(fig.5, p.106) though this is not always necessary for a simple pinhole will do.

Most careful observers looking at a bright surface or a light through a pinhole held 20 to 50 cm in front of the eye can discern within the limits of the hole a pattern of black lines, circles, and other shapes . The size of the seen field depends on the size of the pupil rather than the size of the hole. When a screen is introduced from below near the eye, the image is shaded from above, and vice versa, that is, it is inverted - the rays converge and cross, as was seen when looking at the distant acuity chart. When a strong concave lens (-20 D) is held in front of the eye the entoptic image is magnified and sharp.

Some of the seen images move vertically with blinking, indicating that they are on the surface of the cornea. Others remain still, do not change much from day to day, and differ between eyes and between persons. They seem to represent local optical refractive variations in the normal lens rather than opacities, and are therefore well perceived also by observers with good vision.

**Double pinholes**

Illustrating the rectilinear propagation of light, Christoph Scheiner (1575-1650) explained theoretically how one side of an object projected through a pinhole would be obscured by a screen introduced near the eye from the opposite side. (Fig. 2, p.105).[15]

He also reported the effects seen when looking monocularly through two pinholes pierced in a board about 2-3 mm apart, today known as the Scheiner disc.[13, 14]

The two images thus produced reunite when an emmetropic eye is focusing at distance. They cross in myopia, and separate in hyperopia , documenting for the first time the geometrical optics of the eye deduced theoretically by Kepler a few years earlier.[15]

Prerequisite is a pupil wider than the distance between the holes, and relaxed accommodation. Some modern keratometers and autorefractors were built on the principle of this phenomenon.

Cogan invented a card with a series of double pinholes separated at given different distances. Held in front of the eye, when the two images just touch one another the width of the pupil corresponds to the distance between the two holes.[16]

A double pinhole device was also used to demonstrate the dependency of accurate accommodation on correct depth perception.[17]

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